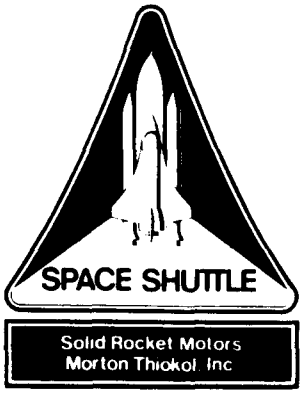

TWR-18609

FORWARD EXIT CONE LDI INTERFACE TESTING AND ANALYSIS

May 1989

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

Contract No. NAS8-30490

DR. No. 3-5

WBS.No. 4B102

MORTON THIOKOL, INC.

Aerospace Group

Space Operations

P.O. Box 707, Brigham City, Utah 84302-0707 (801) 863-3511

MORTON THIOKOL, INC.
Space Operations

TWR-18609
FORWARD EXIT CONE LDI INTERFACE TESTING and ANALYSIS

Prepared by:

Peggy R. Kelley 05/10/89
P. R. Kelley
Nozzle/Flex Bearing Design

Approved by:

J. E. Fonnesbeck, Supervisor
Nozzle/Flex Bearing Design

D. R. Siler
NDE RSRM Quality Engineering

D. D. Bright
Composite Structures

R. K. Wilks, Manager
Component Design

E. L. Diehl
RSRM Nozzle Programs

A. P. Thompson
Nozzle Materials and Process

5-24-89
R. P. Golde
RSRM Nozzle Projects

Systems Safety

Reliability

Systems Planning Certification

PC Tydeck 5-24-89
Release (ECS 1844)

REVISION ____

DOC NO. | VOL
SEC | PAGE

TABLE OF CONTENTS

FIGURES

1.0 INTRODUCTION

Low Density Indications/Low Density Lines (LDIs/LDLs) occur frequently on radiographs of nozzle phenolic parts. LDIs/LDLs can be caused by delaminations, voids, resin-rich, or resin-poor areas. Most LDIs/LDLs are resin rich areas which are formed during the tape wrapping and cure operation. These indications appear on the tangential radiograph exposures as dark triangles at the end of plies (LDIs) or as dark lines around individual or groups of plies (LDLs).

This report summarizes the mechanical testing performed to thoroughly characterize low density indications located between the Carbon Cloth Phenolic (CCP) to Glass Cloth Phenolic (GCP) material interface within the Forward Exit Cone (FEC), Part Number 5U52839-402 Serial Number 16.

2.0 SUMMARY AND CONCLUSIONS

2.1 Summary

Radiographic inspection of the Space Shuttle Redesigned Solid Rocket Motor (RSRM) nozzle FEC reveals LDIs at the carbon liner to glass insulator interface. The indicated LDIs are resin-rich areas formed at the CCP/GCP interface in a triangular shape at the ends of plies that have been applied at an angle. Also seen were Ply-End Folds (PEFs) of the GCP that lay

parallel to the interface (**Figure 1**). Interface LDIs and PEFs were tested for ultimate strength by both tensile and shear test methods.

The nature of the material tested proved to be typical composite and resin-rich areas. Low-energy radiographs were taken of both kinds of test specimens. They confirmed the presence of and number of LDIs and PEFs in each specimen. The x-ray data was compared with the maximum stress required to break each specimen and with the number and type of LDIs from a visual examination of each specimen. Comparison of radiographs of LDIs and PEFs and their strength data indicated no apparent correlation between failure strength and LDIs or PEFs.

2.2 Conclusions

LDIs and PEFs at the carbon to glass interface of the RSRM nozzle FECs are inherent to design and process. Testing of component ultimate strength by tensile and shear test methods show that the LDIs at the CCP/GCP interface that are inherent to design and process do not result in loss of strength at the interface. Ply end LDIs and PEFs are an acceptable condition.

Data comparisons were made for all test results. There was no distinguishable correlation between the presence of LDIs or PEFs in the test specimens and their tested ultimate strengths. The test results showed that the number of indications, type, or size tested have no discernable effect on the specimens.

3.0 DISCUSSION

3.1 Manufacturing Techniques

The FEC is manufactured in the following sequence:

1. Tape wrap CCP
2. Cure CCP
3. Machine CCP
4. Apply SC-1008 to machine surface
5. Tape wrap GCP
6. Cure GCP
7. Machine GCP
8. X-ray liner.

The GCP is wrapped parrallel to the nozzle centerline. This wrap angle, combined with the thickness of the GCP tape, creates small triangular regions which are filled with either the resin that is applied prior to GCP overwrap and/or with the resin contained within the GCP. The size of these triangular regions may be increased during the wrap operation by a significant increase in the GCP layup tracking rate along the smooth carbon machined surface.

3.2 Nondestructive Evaluation-Radiography

All specimens were radiographed with a Torrex 120D equipped with a 0.6-mm focal spot and a 0.6-mm beryllium window. The tensile buttons were radiographed normal to the ply layers and were rotated, when necessary, to obtain a clear image of the LDIs/LDLs. KODAK M Ready Pack film was placed

48 inches from the beam and exposed for approximately 275 seconds at 100 kV and 5 Ma. The buttons were exposed for a target density of 2.5 H&D units in the GCP. Lead numbers were placed below each specimen for easy identification.

For the double notch shear samples, the KODAK M Ready Pack film was placed 48 inches from the beam and exposed for approximately 1400 seconds at 60 kV and 5 Ma. Lead numbers were placed along each block of samples for easy identification. These samples were exposed for a target density of 2.3 H&D units in the GCP.

3.3 Tensile Testing

The tensile test specimen used to determine the strength at the carbon to glass interface is shown in **Figure 2**. Each specimen was removed from the component being tested using a 1.50-inch core drill. Once removed, each core was machined to the dimensions shown in **Figure 2** with the interface aligned at the middle of the test section of the tensile button.

The interface of the FEC is totally blanketed with the ply end LDI condition under investigation. Ply-end LDIs are formed when more than one tape is stacked on top of each other. The tape ply edges form a gap that is filled with resin during cure. **Figure 3** shows these stacked plys and gaps.

After machining, tensile buttons are bonded to steel pull rods using epoxy adhesive (EA934NA). The specimen is then pulled to failure in tension using a 0.05 inch per minute pull rate. The mean stress for all of the specimens was 2676.73 psi with a standard deviation of 620.22. The trend plot of specimens with and without LDIs (**Figure 4**) shows no correlation between LDIs and strength. Ply-end folds were evaluated and no correlation was found. **Figure 5** shows the distribution for the number of folds versus strength. Statistics were run on groups 0-1 Folds and 2-4 Folds. Average strengths (and coefficient of variations) are 2783.21 (14.47) and 2679.00 (20.26) respectively. The data base is not large enough to draw a conclusion about the effect of the folds on part strength.

3.4 Double Notch Shear Testing

Double notch shear specimens were used to test the strength of the carbon to glass interface as shown in **Figure 6**. Specimens were machined with the interface aligned with the middle of the specimen thickness. Specimens were compressed along the length of the specimen at a rate of 0.05 inch per minute. The mean stress for all of the specimens was 9010.08 psi with a standard deviation of 1948.45. The trend plot of specimens with and without LDIs (**Figure 7**) shows no correlation between LDIs and strength. Ply-end folds were evaluated and no correlation was found. **Figure 8** shows the distribution for the number of folds versus strength. Statistics were run on groups 0-1 Folds and 2-8 Folds. Average strengths (and coefficient of variations) are 8870.57 (19.95) and 9128.93 (23.17) respectively. As

with the tensile specimens the data base is not large enough to draw a conclusion about the effect of the folds on part strength.

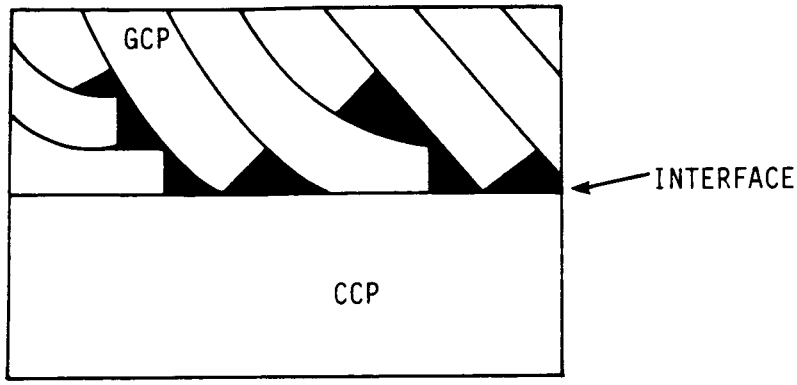

Figure 1 Glass Cloth Phenolic Interface Folds

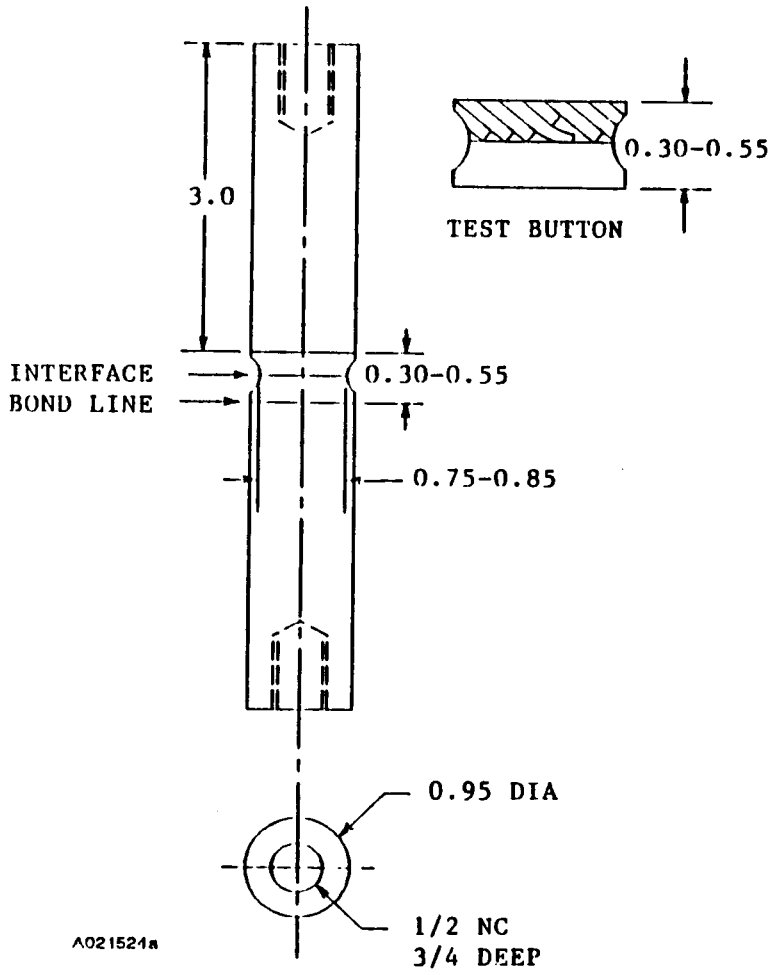

Figure 2 Interface Tensile Specimen Configuration

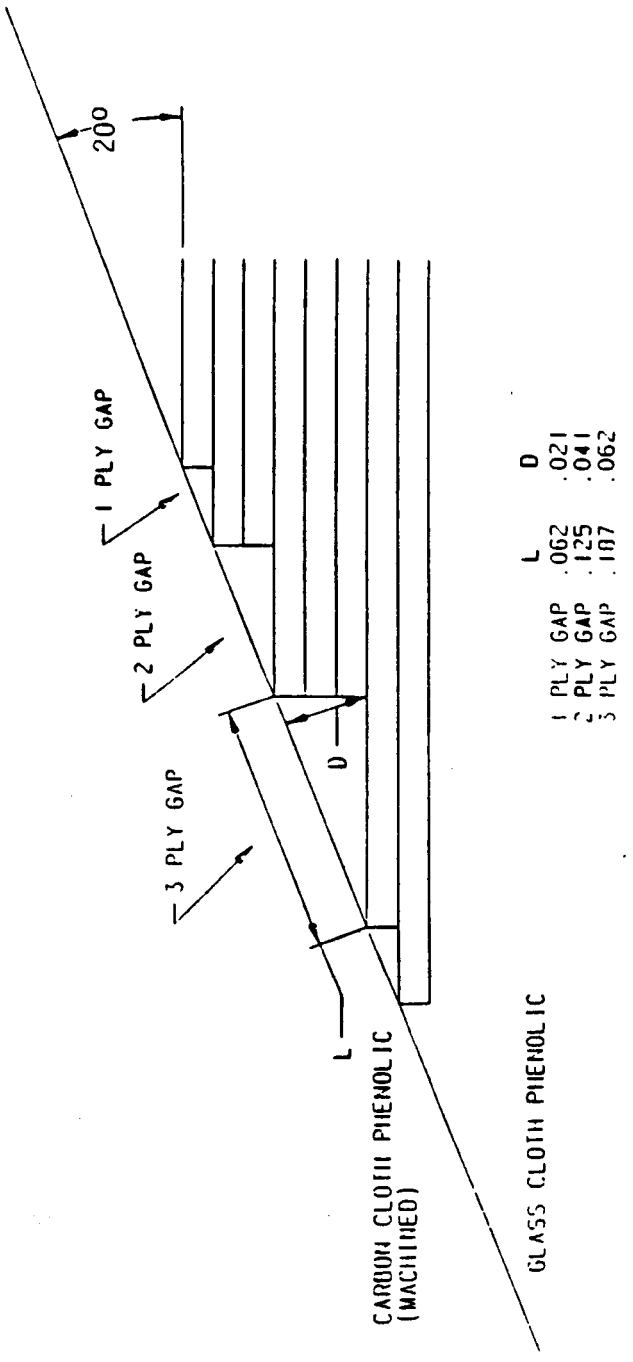

Figure 3 Interface Low-Density Indications

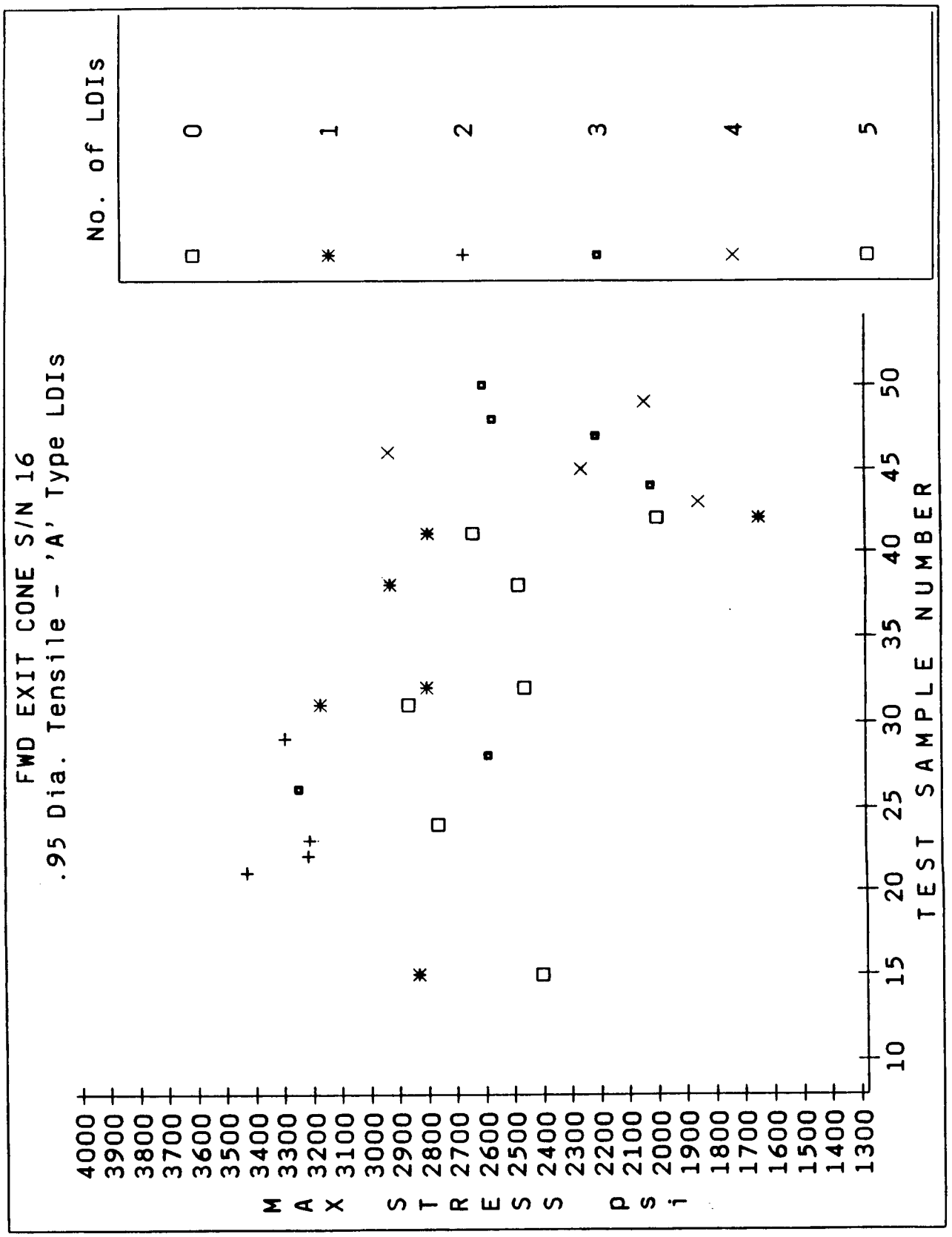

Figure 4 Fwd Exit Cone S/N 16 - 0.95 Dia Tensile ("A" Type LDIs)

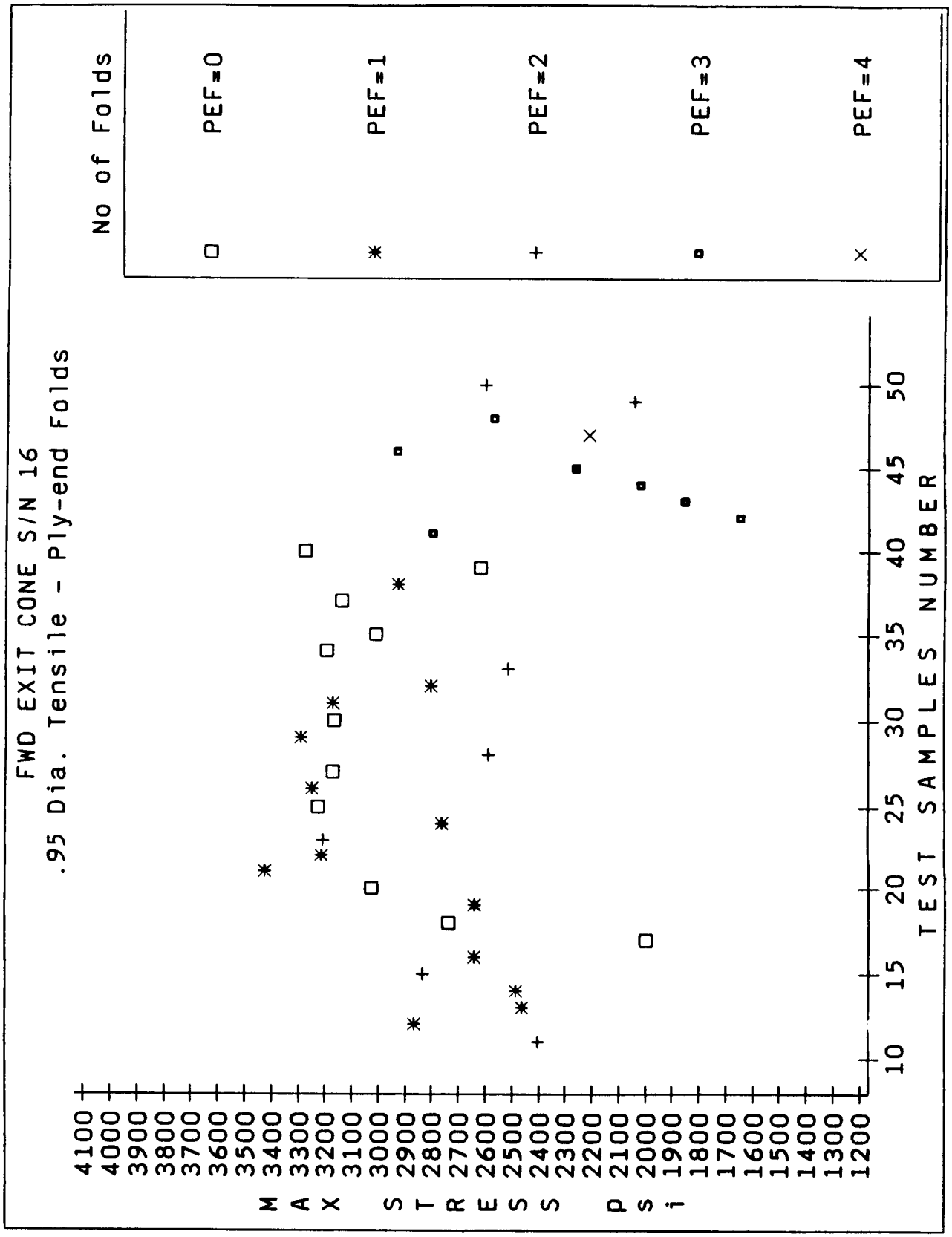

Figure 5 Fwd Exit Cone S/N 16 - 0.95 Dia Tensile (Ply-End Folds)

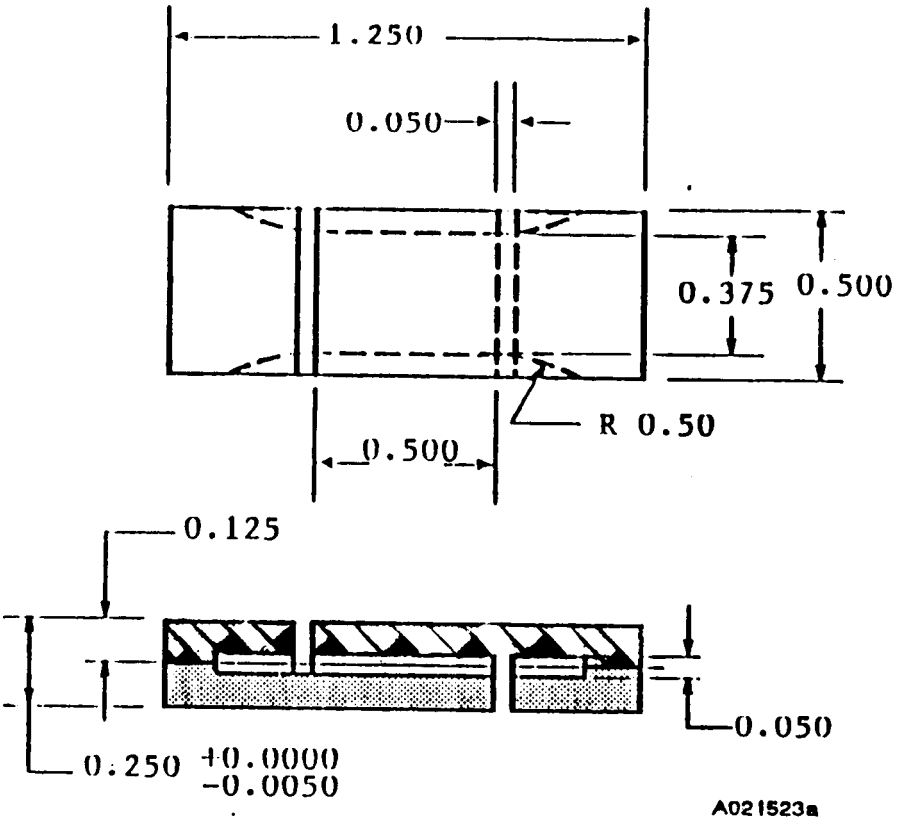

Figure 6 Double Notch Shear Specimen Configuration

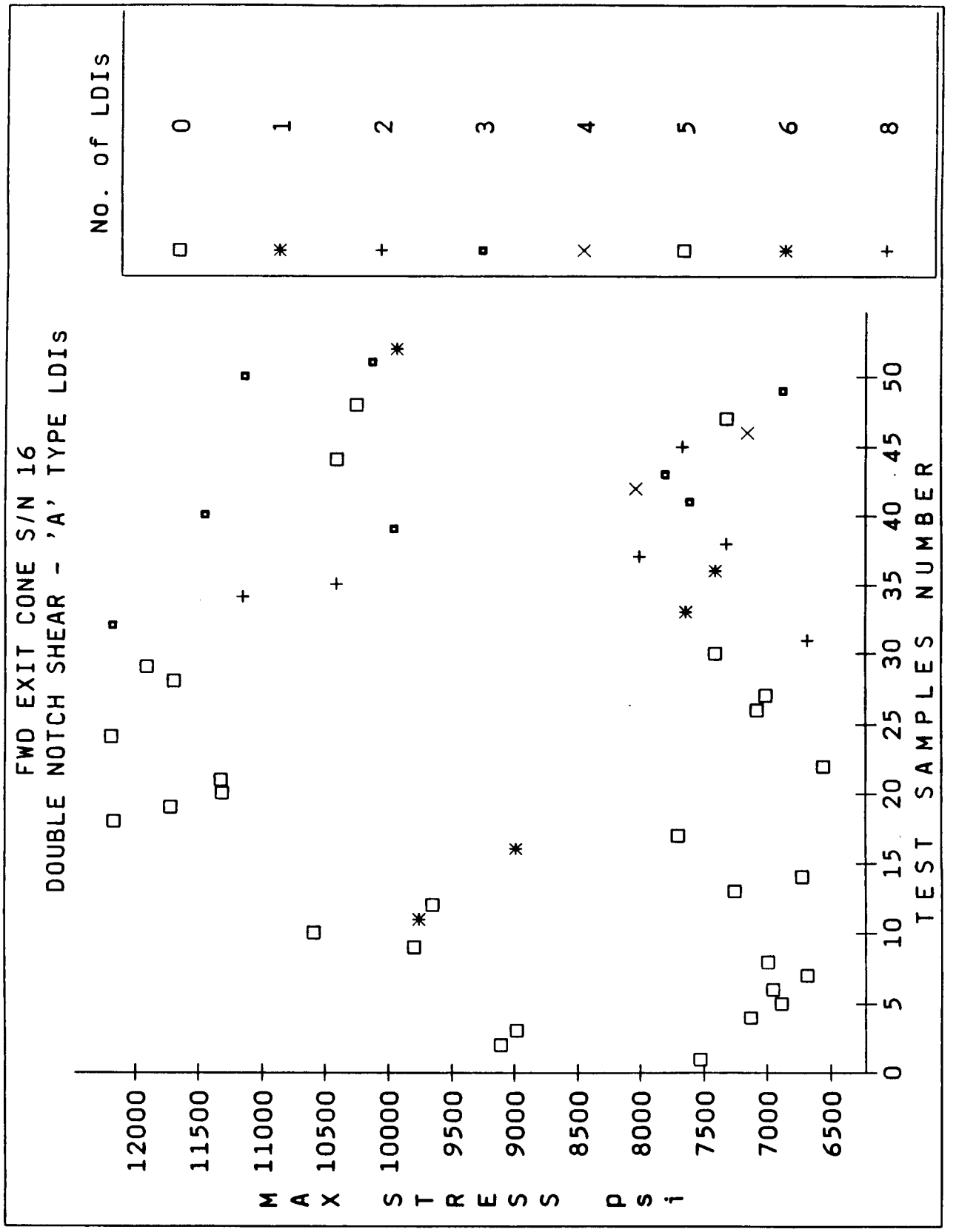

Figure 7 Fwd Exit Cone S/N 16 - Double Notch Shear ("A" Type LDIs)

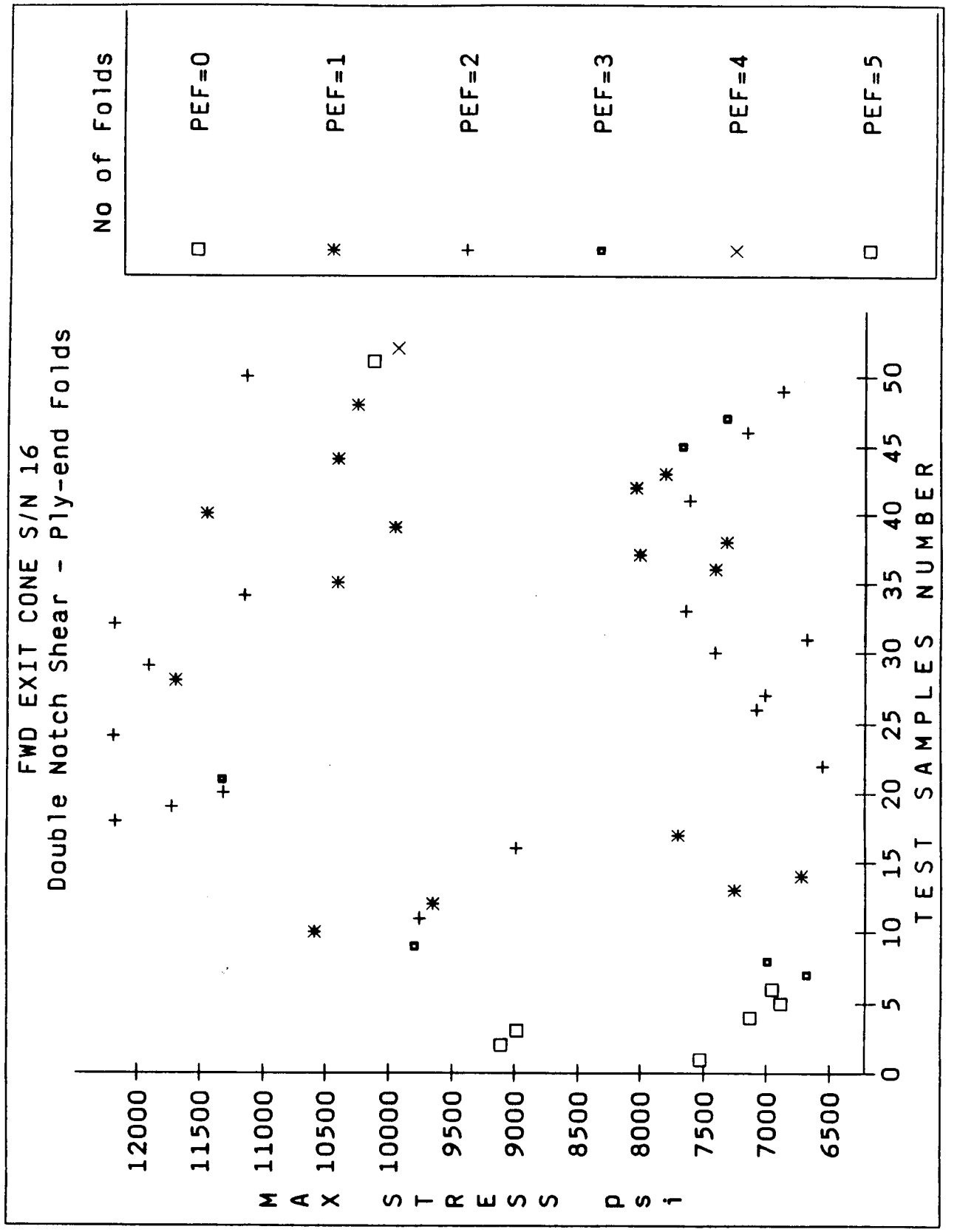

Figure 8 Fwd Exit Cone S/N 16 - Double Notch Shear (Ply-End Folds)

DISTIBUTION

NAME	M/S
R. GOLDE	L10
D. BRIGHT	L22
A. THOMPSON	242
D. SILER	882
E. DIEHL	E14
J. FONNESBECK	L23A
R. WILKS	L23
R. LOEVY	L23A
M. OJA	L23A
P. KELLEY	L23A
T. OTT	MTI/MSFC
PRINT CRIB	K23B1
LIBRARY	064A